AD 296 857

QUARTERLY PROGRESS REPORT NO. 3
SEGMENTED ROCKET MOTOR CASE PROGRAM

15 JANUARY 1963 **DOUGLAS REPORT SM-42911**

MISSILE & SPACE SYSTEMS DIVISION
DOUGLAS AIRCRAFT COMPANY, INC.
SANTA MONICA CALIFORNIA

DOUGLAS

QUARTERLY PROGRESS REPORT NO. 3
SEGMENTED ROCKET MOTOR CASE PROGRAM

15 JANUARY 1963
DOUGLAS REPORT SM-42911

R.G. Carpenter
T.R. Jeffus

15 October 1962 – 15 January 1963

Approved by:

D.V. Magill
Chief, Missile Structure Systems Section

Prepared for
Space Systems Division
Air Force Systems Command
Rocket Research Laboratories
Edwards, California

Contract No. AF 04(611)-8184
AFSC Project No. 3059
AFSC Task No. 305909
Program Structure No. 750G

MISSILE SYSTEMS ENGINEERING | MISSILE & SPACE SYSTEMS DIVISION
DOUGLAS AIRCRAFT COMPANY, INC.

NOTICES

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever. The fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded, by implication or otherwise, as in any way licensing the holder, or any other person or corporation, to manufacture, use, or sell any patented invention that may in any way be related thereto. Neither may it be regarded as conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

FOREWORD

This is the third quarterly report on the work performed by Douglas Aircraft Company under USAF Contract AF 04(611)-8184 during the period from 15 October 1962 to 15 January 1963. The contract is a 13-month research and development program directed toward design, development, fabrication, and testing of lightweight motor case segments, culminating in a design applicable to large segmented solid propellant rocket motors.

ABSTRACT

This is an interim report on a research and development program directed toward design, development, fabrication, and testing of lightweight motor case segments, culminating in a design applicable to large (160 to 240-in. diameter) segmented solid propellant rocket motors.

A summary of work accomplished on the bench test program and on the 43-in. dia. subscale segments is included. Douglas-funded programs related to the segmented booster program are discussed. Tests completed during the current report period are described in detail.

TABLE OF CONTENTS

ILLUSTRATIONS

1.0 INTRODUCTION

1.1 Summary of Program Scope and Approach

This document is the third quarterly progress report for Contract No. AF 04(611)-8184 sponsored by Rocket Research Laboratories, Edwards, California. The objective of this contract is to conduct a comprehensive program for the design, analysis, development, fabrication, and testing of a complete 43-in. dia. subscale solid propellant rocket motor segment. An optimum segment design will be determined which will incorporate minimum weight, high reliability, easy segment assembly and disassembly, and low over-all cost. In addition, the feasibility of scaling the subscale 43-in. dia. segment to full size 160 and 240-in. diameters will be determined. Propellant and aerodynamic heating, flight and ground handling loads, and fabrication procedures expected for the full-size segments will be considered.

1.2 Summary of Progress Reported in Quarterly Progress Reports No. 1 and 2

Quarterly Progress Report No. 1 included discussions of the basic motor case segment design concept, of the design of a 43-in. dia. subscale segment, and of the test programs being conducted to implement segment design. Work accomplished on the 43-in. dia. segments and on the test program, as of 15 July 1962, was summarized, and completed tests were described in detail. Drawings of the 43-in. dia. segment and its proof-test assembly were included. Analytical techniques developed to assist in segment design and a strength analysis of the 43-in. dia. segment were presented in the Appendices.

Quarterly Progress Report No. 2 included a summary of work accomplished on the 43-in. dia. segments and on the test program as of 15 October 1962. Tests completed during the report period (15 July 1962 to 15 October 1962) were described in detail. A computer program for the determination of shear and direct stresses in a lap joint and a revision of the strength analysis,

originally presented in Quarterly Progress Report No. 1, were included in the Appendices.

1.3 Summary of Work Accomplished from 15 October 1962 to 15 January 1963

All work has been accomplished within the originally established budget with approximately 74% of the total program budget having been expended as of 15 January 1963.

A summary of work accomplished during the current report period follows. The topics listed are presented in greater detail in the Discussion (Section 2.0).

a. Status of Bench Test Program (See Section 2.1 of Discussion)

All bench tests have been completed except for the sixth 6-in. dia. by 18-in. long segmented joint test specimen (Dwg. No. 1A35804), and the twelve 25 1/2-in. dia. by 20-in. long compression test cylinders (Dwg. No. 1A35803).

Testing of the sixth segmented joint test specimen is approximately four months behind schedule. This lag developed from a decision to fabricate and test only one segmented joint test specimen at a time so that any modifications indicated by test results could be integrated into the design and fabrication of subsequent specimens.

Fabrication of the 25 1/2-in. dia. compression test cylinders is approximately 2 weeks behind schedule, but this lag will not affect fabrication and testing of other items.

The following bench tests were completed during the current report period: eighteen lap joint specimens (Dwg. No. 1A39050),

two 4-in. dia. by 9-in. long interlaminar shear, tension test specimens (Dwg. No. 1A35801), and three 4-in. dia. by 4 1/2-in. long interlaminar shear, metal-to-glass, compression test specimens (Dwg. No. 1A35799), four 6-in. dia. by 18-in. long. segmented joint test specimens (Dwg. No. 1A35804), six 4-in. dia. by 6-in. long interlaminar shear, glass-to-glass, compression test specimens (Dwg. No. 1A35800), eight 16-in. dia. by 12-in. long compression test cylinders (Dwg. No. 1A35802), four wedge shear test specimens (Dwg. No. 1A39826), and four wedge anchorage test specimens (Dwg. No. 1A58249). Any completed tests not included in this list were reported in previous progress reports.

b. Status of 43-In. Dia. Segments (See Section 2.2 of Discussion.)

Tooling for the 43-in. dia. segments is completed. Six staves for construction of the 43-in. dia. segments have been fabricated. Two of the 43-in. dia. test closures were assembled "back-to-back" and proof-tested. The clamps and clamp retaining band were modified because of poor results obtained in this test. The closures will be subjected to another proof-test using these modified clamps and band.

Fabrication of the first 43-in. dia. segment is behind schedule approximately 12 weeks. A concerted effort is being made to remedy this situation so as to have the final pair of segments completed and tested within the time originally allotted for this program.

c. Douglas-Funded Programs (See Section 2.3 of Discussion)

Several Douglas-funded programs are being conducted to assist the segmented booster program. These programs are:

1. NOL Ring Test Program

Twenty-one NOL (Naval Ordnance Laboratory) rings have been tested in addition to the 50 rings that were reported in Quarterly Progress Report No. 2. These rings were tested for resin system evaluation.

2. Douglas Pre-Preg Tape Development and Production Program

The Douglas-funded fiberglas tape-making machine is producing tape which is being used for construction of bench test specimens and 43-in. dia. segments.

3. Stave Anchoring Test Program

Douglas is conducting a comprehensive program for the development of optimum methods for stave anchoring.

2.0 DISCUSSION

A discussion of work accomplished during the current report period follows. Work accomplished previous to the current report period was adequately reported in Quarterly Progress Reports No. 1 and 2, and therefore, will not be discussed in this report.

2.1 Bench Testing

One type of test has been added to the ten types of bench tests described in Section 2.5 of Quarterly Progress Report No. 2. This test is a wedge anchorage test (Dwg. No. 1A58249 - see Section 2.1.9 below) for evaluating a stave anchoring concept similar to that used in the wedge shear test (Dwg. No. 1A39826).

A brief description of the testing and fabrication status of the bench test program follows.

2.1.1 Lap Joint Specimens

Eighteen lap joint specimens (Dwg. No. 1A39050) have been tested in addition to the 15 specimens reported in Report No. 1. These specimens were tested to evaluate the bond strength of six different steel-to-fiberglas adhesives under cure conditions applicable to the segmented booster joint.

Each specimen had 1-in. wide by 4 1/2-in. long 4130 steel tapered end fittings bonded to a 1-in. wide by 6-in. long by 1/8-in. thick HTS fiberglas laminate. The steel end fittings were grit-blasted, treated with "Prebond 700" (a Bloomingdale Rubber Co. product), and rinsed and dried. The fiberglas laminates were grit-blasted. The parts were assembled with a 2-in. double over-lap and press-bonded (at 40 to 50 psi) for 2 hours at 200°F and 4 hours at 300°F.

The specimens were loaded in tension at a rate of 1250 lbs. per minute until failure (see Figure 1 for typical failures). Test results are shown in Table 1. AF-300 produced a stronger bond than did any of the other adhesives.

2.1.2 4-In. Dia. by 9-In. Long Interlaminar Shear Tension Test Specimens

Two 4-in. dia. by 9-in. long interlaminar shear tension test specimens (Dwg. No. 1A35801) have been tested in addition to the ten specimens reported in Report No. 2. These two specimens were fabricated using tapered end fittings salvaged from the 1A35801-503 "reworked" specimen tests. The specimens were assembled identical to the -503 "reworked" specimens except that Lefkoweld No. 157 paste adhesive was substituted for FM-97 film adhesive. Also, the specimens were cured for 3 hours at 180°F, 4 hours at 250°F, and 4 hours at 350°F instead of 2 hours at 120°F, 4 hours at 180°F, and 4 hours at 250°F. This change in cure cycle was made to obtain better adhesive curing.

The two specimens were tested in tension in the same way as described in Report No. 2 for the first ten specimens. The metal-to-fiberglas bond failed in both specimens (see Figure 2). Test results are presented in Table 2.

2.1.3 6-In. Dia. by 18-In. Long Segmented Joint Test Specimens

The second, third, fourth, and fifth 6-in. diameter by 18-in. long segmented joint test specimens (Dwg. No. 1A35804) have been tested with results as shown in Table 3. A description of fabrication procedures and test results for each specimen follows:

a) Specimen No. 2. The second specimen was assembled on a salt mandrel as follows:

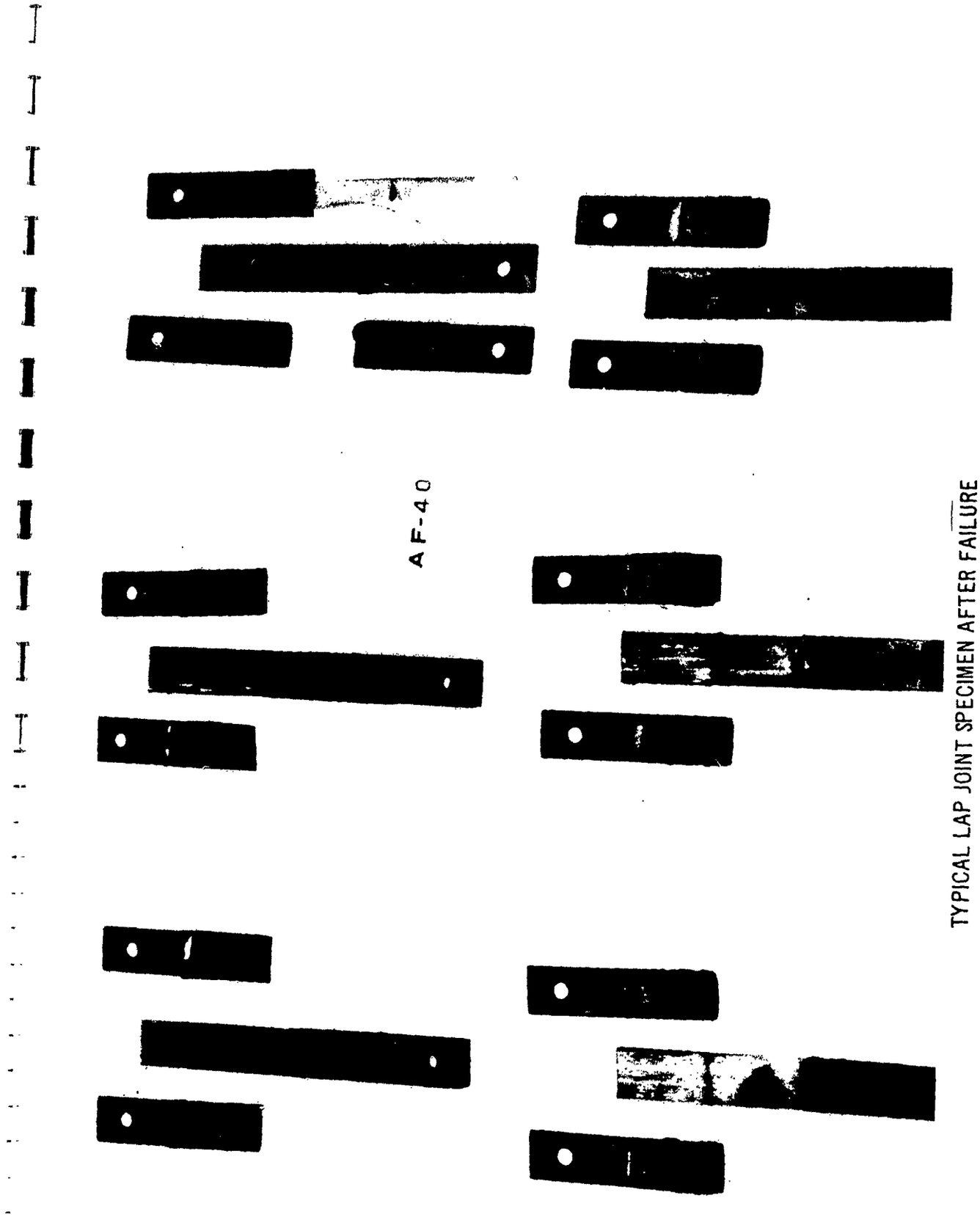


FIGURE 1

TABLE 1

Lap Joint Test Specimens (For Adhesives Evaluation)

Code Drawing 1A39050	Materials				Failure Stress (psi)	Mode of Failure*
	Glass	Resin	Metal	Adhesive		
No. 1	HTS	X2638.6/ MNA/BDMA	4130 Steel	Lefkoweld -157	1,145	100%L/50%L-C
2					1,283	75%L-25%C/90%L-10%C
3					1,103	90%C-10%L/60%C-40%L
4	HTS	X2638.6/ MNA/BDMA	4130 Steel	BR-89	1,260	100%L/100%L
5					1,305	100%L/80%L-20%C
6					1,225	100%L/100%L
7	HTS	X2638.6/ MNA/BDMA	4130 Steel	EC-2216	1,385	100%C/90%L-10%C
8					1,180	100%C/90%L-10%C
9					1,500	100%C/90%C-10%L
10	HTS	X2638.6/ MNA/BDMA	4130 Steel	Lefkoweld -108	1,265	100%L/90%L-10%C
11					1,350	50%L-C/50%L-C
12					1,280	100%L/80%L-20%C
13	HTS	X2638.6/ MNA/BDMA	4130 Steel	AF-40	193	Adhesive failed in all specimens. Adhesive did not flow properly during cure.
14					1,490	
15					932	
16	HTS	X2638.6/ MNA/BDMA	4130 Steel	AF-300	2,230	100%L/100%L
17					2,060	100%C/75%C-25%L
18					2,695	100%L/100%L

*Failure Code: C = cohesive failure, A = adhesive failure, L = laminate failure. Failure modes for different surfaces are separated by a slash (/).

FIGURE 2

TYPICAL INTERLAMINAR SHEAR TENSION TEST SPECIMENS AFTER FAILURE

TABLE 2

4-In. Dia. by 9-In. Long Interlaminar Shear Tension Test Specimens

Code Drawing 1A35801	Materials				Length of Shear Joint (in.)	Failure	
	Glass	Resin	Metal	Adhesive		Total Load (lbs)	Shear Stress (psi)
-503 No. 1 (Used hardware from -503 No. 1 - "re-worked" specimen)	HTS Single End	X2638.6/ MNA/BDMA	4140 Steel Tube	Lefkoweld -157	3	62,500	1,658
-503 No. 2 (Used hardware from -503 No. 2 - "re-worked" specimen	HTS Single End	X2638.6/ MNA/BDMA	4140 Steel Tube	Lefkoweld -157	3	59,000	1,565

TABLE 3

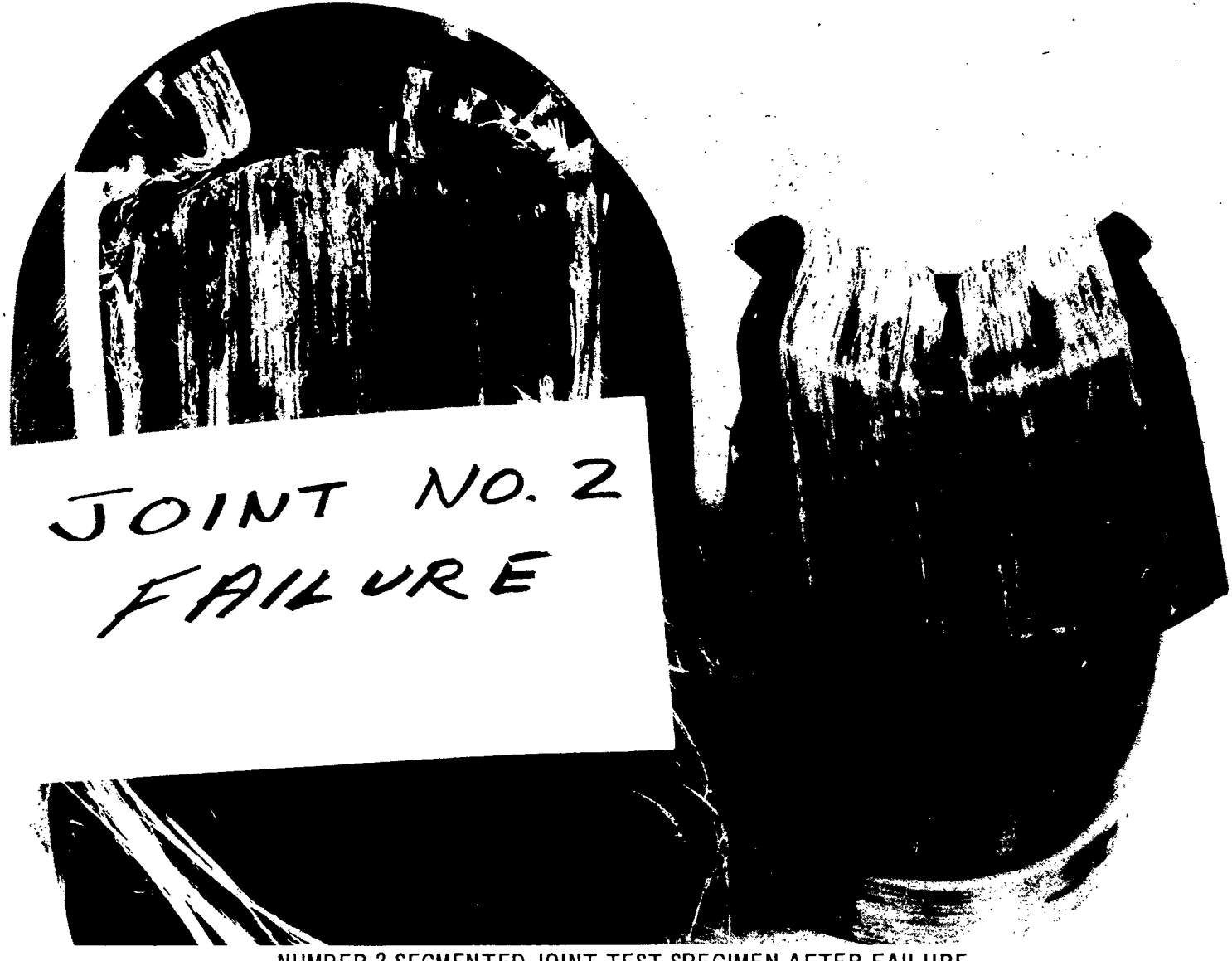
6-In. Dia. by 18-In. Long Segmented Joint Test Specimens

Code Drawing 1A35804	Material				Cure Cycle	Comments	Failure Load (lbs.)	Mode of Failure
	Glass	Resin	Metal	Adhesive				
No. 2	HTS	X2638.6/ MNA/BDMA	4140 Steel Tube	Lefkoweld -157	3 hrs. at 180°F, 4 hrs. at 250°F, and 4 hrs. at 350°F.	Had "hand-laid" longitudinals	181,000	Fiberglas-to-metal bond failed. Staves pulled out of joint.
No. 3	HTS	X2638.6/ MNA/BDMA	4140 Steel Tube	AF-300	2 hrs. at 200°F and 4 hrs. at 350°F.	Had premolded staves. Segmented outer rings were slit.	205,300	Fiberglas-to-metal bond failed. Staves pulled out of joint. Some of longitudinal fibers broke.
No. 4	HTS	X2638.6/ MNA/BDMA	4140 Steel Tube	AF-300 and BR-89	3 hrs. at 180°F, 4 hrs. at 250°F, and 4 hrs. at 350°F.	Had increased thickness in "hook" section of pre-molded staves.	220,000	Stave failed in hook section of the joint.
No. 5	HTS	828-1031/ MNA/BDMA	4140 Steel Tube	FM-97	3 hrs. at 180°F, 4 hrs. at 250°F, and 4 hrs. at 350°F.	Had indentation on inner continuous ring. Outer segmented ring was omitted. Had "hand-laid" longitudinals.	260,000	Longitudinal laminate failed near indentation on inner ring. Fiberglas had not bonded to metal.

Steel end fittings were degreased, sand-blasted, cleaned, and primed with thinned Lefkoweld No. 157. The inner ring end fittings were then installed on the mandrel. Lefkoweld No. 157 paste adhesive was applied to the end fittings and 25 plies of 1/2 inch wide Douglas pre-preg tape were laid up to form the longitudinals. The segmented end fittings were then cleaned and coated with adhesive, as were the inner ring end fittings, and installed. Fifty plies of HTS 20 end roving were applied to form the circumferential wrap. Sixteen pounds of tension per roving were used during wrapping. The assembly was cured 3 hours at 180°F, 4 hours at 250°F, and 4 hours at 350°F. The specimen was then cooled 50°F per hour to prevent cracking.

The specimen was tested in a 400,000 lb. Baldwin compression-tension machine. It was loaded in tension until it failed. Failure occurred at 181,000 lbs. load due to failure of the fiberglas-to-metal bond (Lefkoweld No. 157) which allowed the staves to pull out of the joint (see Figure 3). Failure of the bond at this low load was probably due to diffusion of the adhesive into the fiberglas during cure.

b) Specimen No. 3. The third specimen was identical to the second except as follows: AF-300 film adhesive and pre-molded staves were used instead of Lefkoweld No. 157 adhesive and "hand laid" longitudinals. In addition, the segmented outer rings of the third specimen were slit to allow better matching of the outer rings to the staves. The staves were formed by laying up 29 plies of Douglas pre-preg tape in matched dies and curing for



NUMBER 2 SEGMENTED JOINT TEST SPECIMEN AFTER FAILURE

FIGURE 3

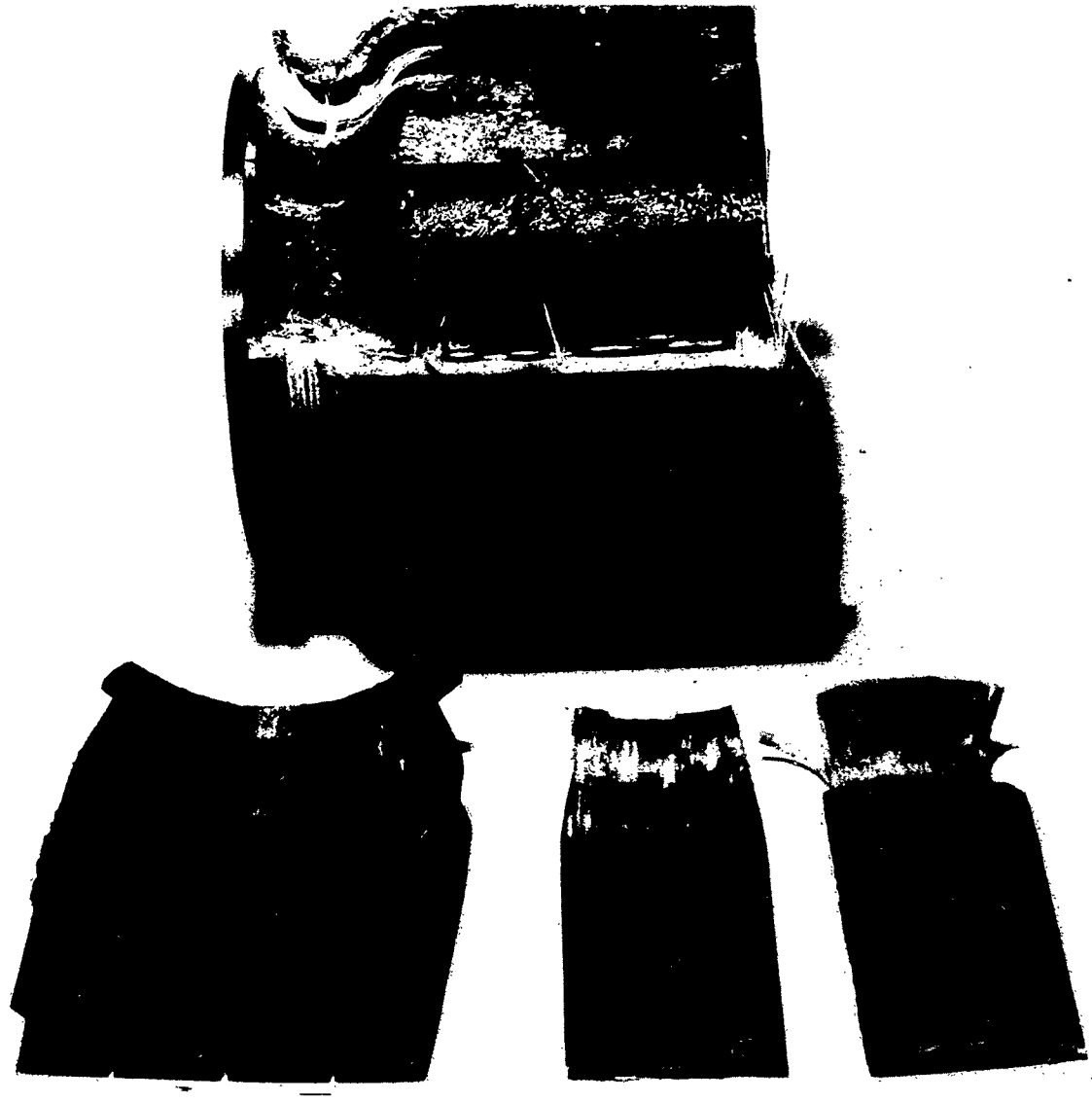
2 hours at 200°F and 2 hours at 350°F. One thousand psi molding pressure was used during cure. Then the staves were assembled on the mandrel, the outer segmented rings were installed, and 50 plies of 20 end HTS roving were applied with 13 lbs. tension to form the circumferential wrappings. The assembly was cured 2 hours at 200°F and 4 hours at 350°F.

The specimen was tested in the same manner as the No. 2 specimen. The specimen failed at a load of 205,300 lbs. due to failure of the fiberglas-to-metal bond (AF-300). This allowed the staves to pull out of the joint (see Figure 4). Some of the longitudinal glass fibers broke due to the bending stresses which were induced when the staves pulled out of the "hook" section of the joint. Failure of the bond was probably due to: a poor fit between the metal fittings and the pre-molded staves; and excess adhesive thicknesses which were observed in the joint area.

c) Specimen No. 4. The fourth specimen was identical to the third except as follows:

1. AF-300 film adhesive was used only on the cylindrical section of the joint.
2. BR-89 paste adhesive was used in the remaining "hook" area of the joint since a better fit can be obtained between the staves and the metal parts in this area by using a paste rather than a film adhesive.

FIGURE 4



NUMBER 3 SEGMENTED JOINT TEST SPECIMEN AFTER FAILURE

3. The thickness of the "hook" section of the pre-molded staves was increased to improve the strength of the joint. The outer segmented rings for the specimen were modified to allow this increased stave thickness.

The fourth specimen failed at a load of 220,000 lbs. In this specimen, the staves failed in the "hook" section of the joint while in the previous three specimens, the staves pulled out of the joint (inadvertently, no picture was taken of this specimen). The staves failed because of a poor stave-to-metal bond and because of stresses induced in the stave by the curvature in the "hook" section of the joint.

d) Specimen No. 5. The fifth specimen was identical to the fourth except as follows:

1. FM-97 film adhesive was used throughout.
2. An indentation was provided on the inner continuous ring to give increased joint strength.
3. The outer segmented ring was omitted so that a better fit between the inner ring and the longitudinal composite could be obtained.
4. Hand-laid longitudinals were used instead of pre-formed staves.
5. 828-1031/MNA/BDMA resin was used instead of 2638.6/MNA/BDMA because of its greater elongation.

The fifth specimen failed at a load of 260,000 lbs. The longitudinal laminate failed near the indentation mentioned in item 2 above (see Figure 5). Inspection of this specimen showed

NUMBER 5 SEGMENTED JOINT TEST SPECIMEN AFTER FAILURE

FIGURE 5

that the longitudinal laminate had not bonded to the inner ring. Further investigation revealed that improper adhesive application procedures had been used during construction of the specimen.

The sixth segmented joint test specimen will be completed within four weeks. This specimen will be modified on the basis of results obtained from the previous tests. Extra precautions will be taken to insure that correct procedures are used during its construction.

2.1.4 4-In. Dia. by 4 1/2-In. Long Interlaminar Shear, Metal-to-Glass, Compression Test Specimens

Three 4-in. dia. by 4 1/2-in. long interlaminar shear, metal-to-glass, compression test specimens (Dwg. No. 1A35799) have been tested in addition to the six specimens reported in Report No. 2. One each of the -1, -501, and -503 configurations were fabricated as follows: 4140 steel fittings were vapor degreased, grit-blasted, and washed with "Prebond 700." FM-97 film adhesive was "heat-tacked" to the steel. Thirty-two plies of Douglas pre-preg tape were applied to form the longitudinal laminate. The "longitudinals" overlapped the fittings of the -1, -501, and -503 specimens, 1/2 inch, 1 inch, and 1 1/2 inches respectively, to give various shear areas. Twenty plies of circumferential wrap were applied over the "longitudinals." Twenty end HTS rovings were used for the circumferential wrap. The rovings were tensioned to 5 1/4 lbs. during wrapping. The assembly was cured 2 hours at 250°F and 4 hours at 350°F.

The specimens were tested in a 400,000 lb. Baldwin compression-tension machine. They were loaded in compression until failure with results as shown in Table 4. The -1 specimen failed at zero load because the adhesive had not bonded to the steel. The -501 and -503 specimens failed in the bond.

TABLE 4

4-In. Dia. by 4 1/2-In. Long, Interlaminar Shear,
Metal-to-Glass, Compression Test Specimens

Code Drawing 1A35799	Material				Length of Lap (In.)	Total Failure Load (lbs.)	Failure Stress (psi)
	Glass	Resin	Metal	Adhesive			
-1 No. 3	HTS Single End	828-1031/ MNA/BDMA	4140 Steel	FM-97	1/2	0*	0*
-501 No. 3	HTS Single End	828-1031/ MNA/BDMA	4140 Steel	FM-97	1	59,000	4,700
-503 No. 3	HTS Single End	828-1031/ MNA/BDMA	4140 Steel	FM-97	1 1/2	52,900	2,800

*No bond adhesion to steel.

2.1.5 4-In. Dia. by 6-In. Long Interlaminar Shear, Fiberglas-to-Fiberglas, Compression Test Specimens

Six 4-in. dia. by 6-in. long interlaminar shear, fiberglas-to-fiberglas compression test specimens (Dwg. No. 1A35800) have been tested. The Number 1 and 2 specimens were fabricated as follows: Sixty-six plies of "interim" tape were applied to a steel mandrel to form the longitudinal laminate (Garalease 225 mold release was used to permit separation of the specimen and mandrel). Twenty plies of 20 end HTS roving were applied for the circumferential wrap. The rovings were tensioned to 7 1/2 lbs. during wrapping. The assembly was cured 3 hours at 180°F, 4 hours at 250°F, and 4 hours at 350°F. The cured specimens were removed from the mandrel in an Arbor press. The No. 3, 4, 5, and 6 specimens were assembled exactly as were the No. 1 and 2 specimens except 45 plies of Douglas pre-preg tape were used for the "longitudinals."

The specimens were tested in a 400,000 lb. Baldwin compression-tension machine. They were loaded in compression until failure with results as shown in Table 5. The portions of the specimens which failed were cut apart for inspection. Typical failures are shown in Figures 6 and 7.

2.1.6 16-In. Dia. by 12-In. Long Compression Test Cylinders

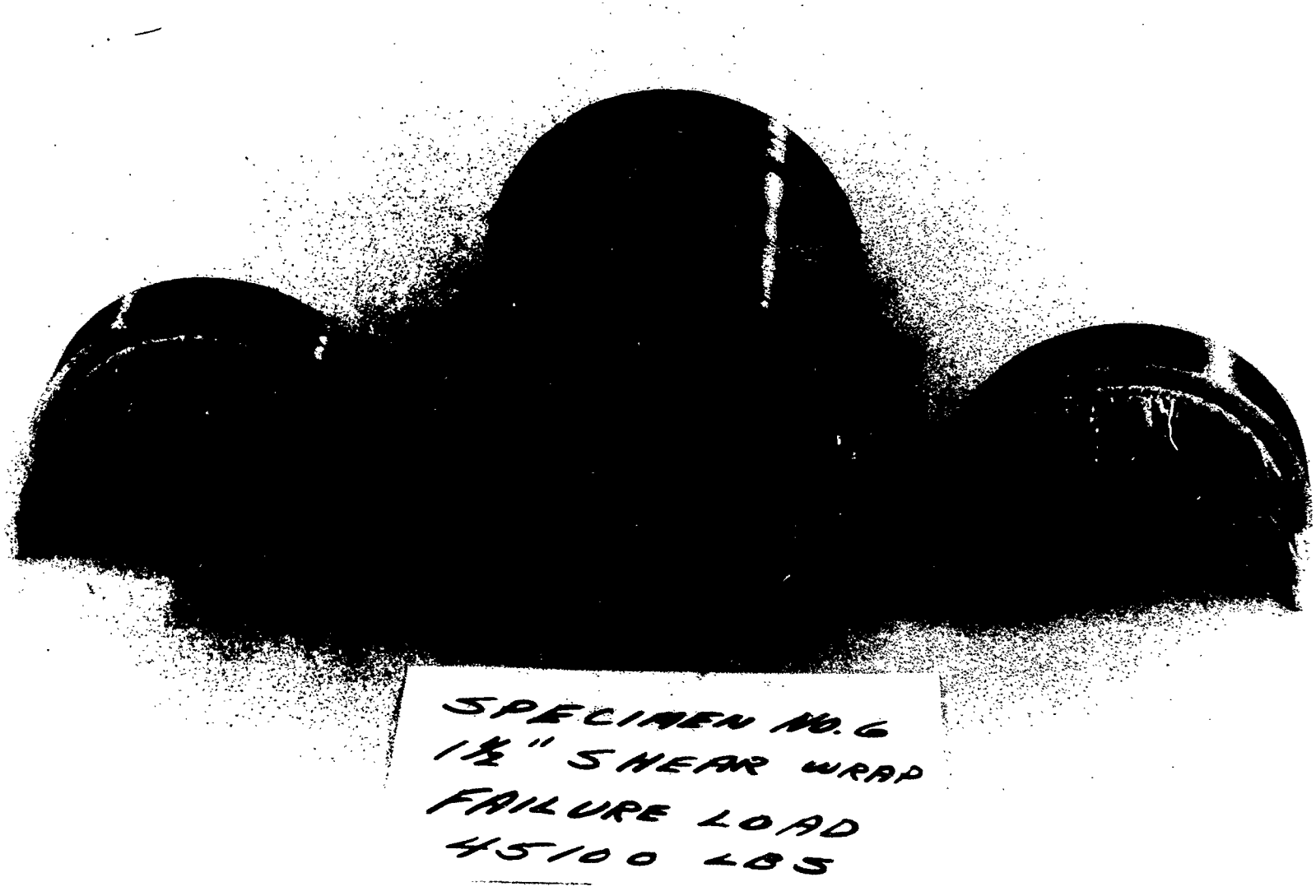
Eight 16-in. dia. by 12-in. long compression test cylinders (Dwg. No. 1A35802) have been tested. The specimens were fabricated as follows: one-half inch wide Douglas pre-preg tape was "hand-laid" on an aluminum mandrel to form the longitudinal laminate in each specimen (Garalease 225 release was used on the mandrel for the first specimen and GS-3 release was used for the remaining specimens). Twenty end HTS roving was used for the circumferential laminate. The laminates were laid up in lengths suitable to allow two specimens to be

TABLE 5

4-In. Dia. by 6-In. Long Interlaminar Shear,
Fiberglas-to-Fiberglas, Compression Test Specimens

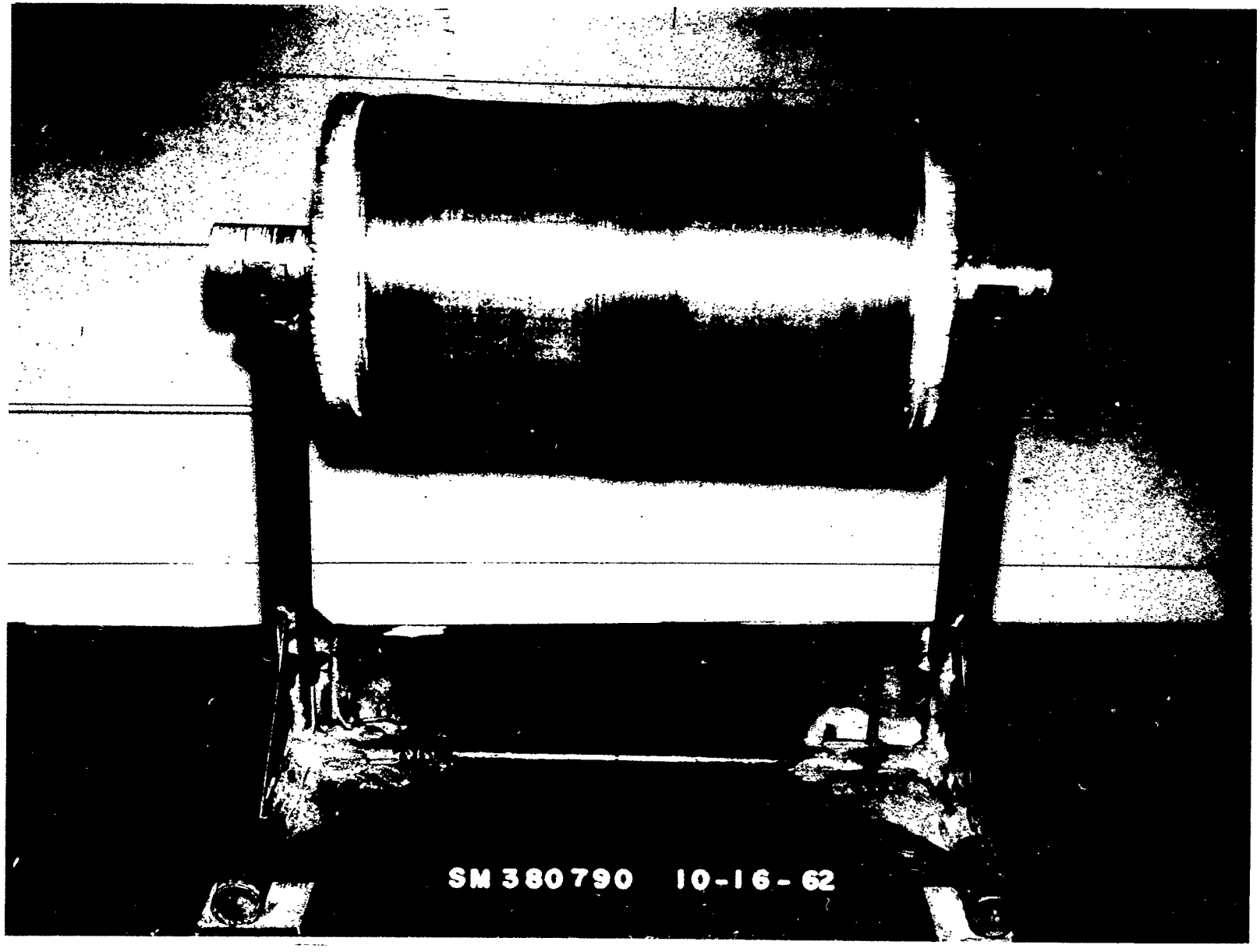
Code Drawing 1A35800	Material		Length of Overlap (In.)	Interlaminar Shear Strength (Compression, psi)
	Glass	Resin		
-1 No. 1	HTS	X2638.6/ MNA/BDMA	.32	8,100
-1 No. 2			.32	8,540
-501 No. 3	HTS	X2638.6/ MNA/BDMA	.94	2,990
-501 No. 4			.94	3,545
-503 No. 5	HTS	X2638.6/ MNA/BDMA	1.44	1,285
-503 No. 6			1.44	2,485

FIGURE 7

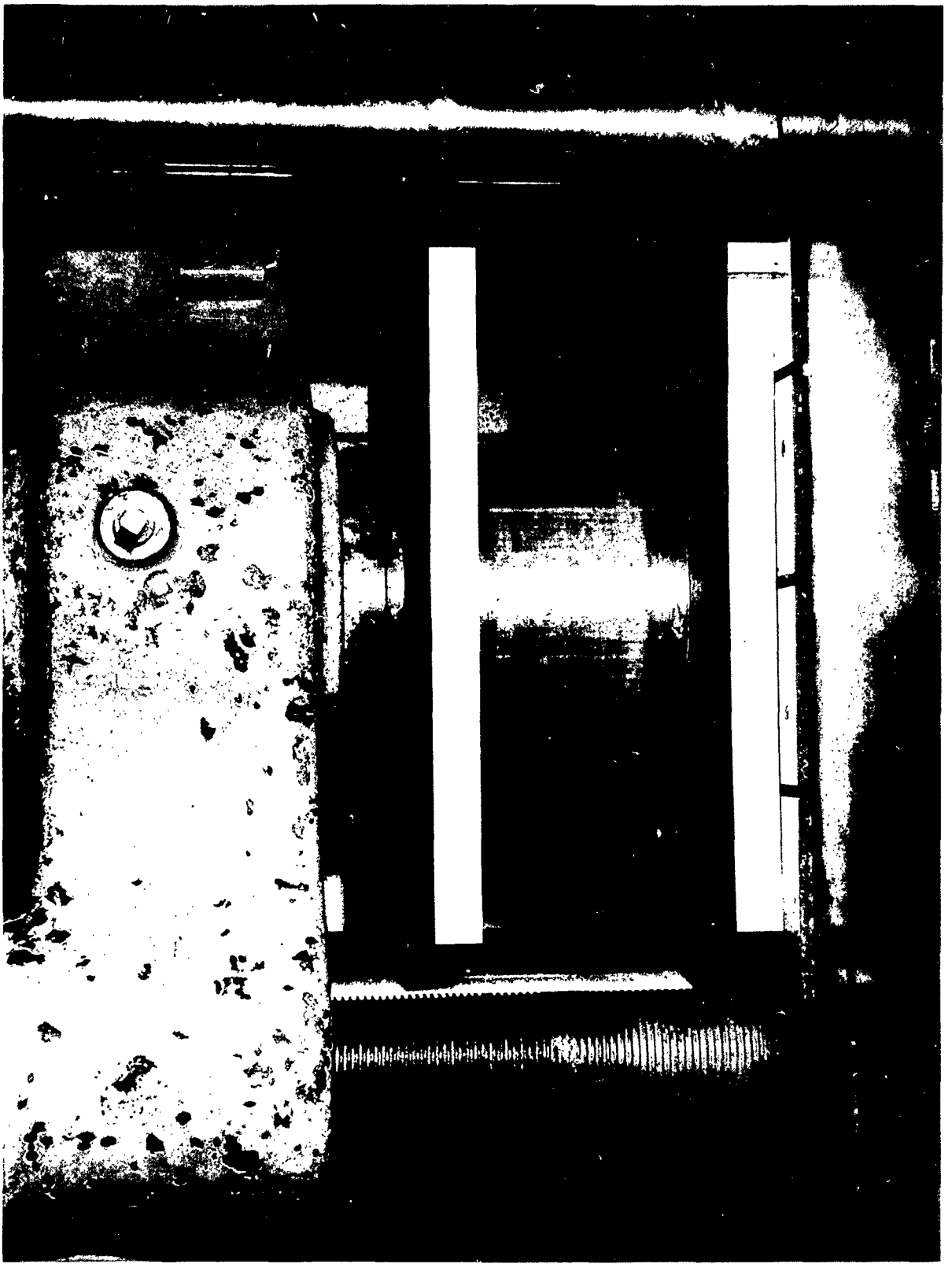


TYPICAL –503 INTERLAMINAR SHEAR, FIBERGLAS-TO-FIBERGLAS, COMPRESSION TEST SPECIMEN AFTER FAILURE

FIGURE 8

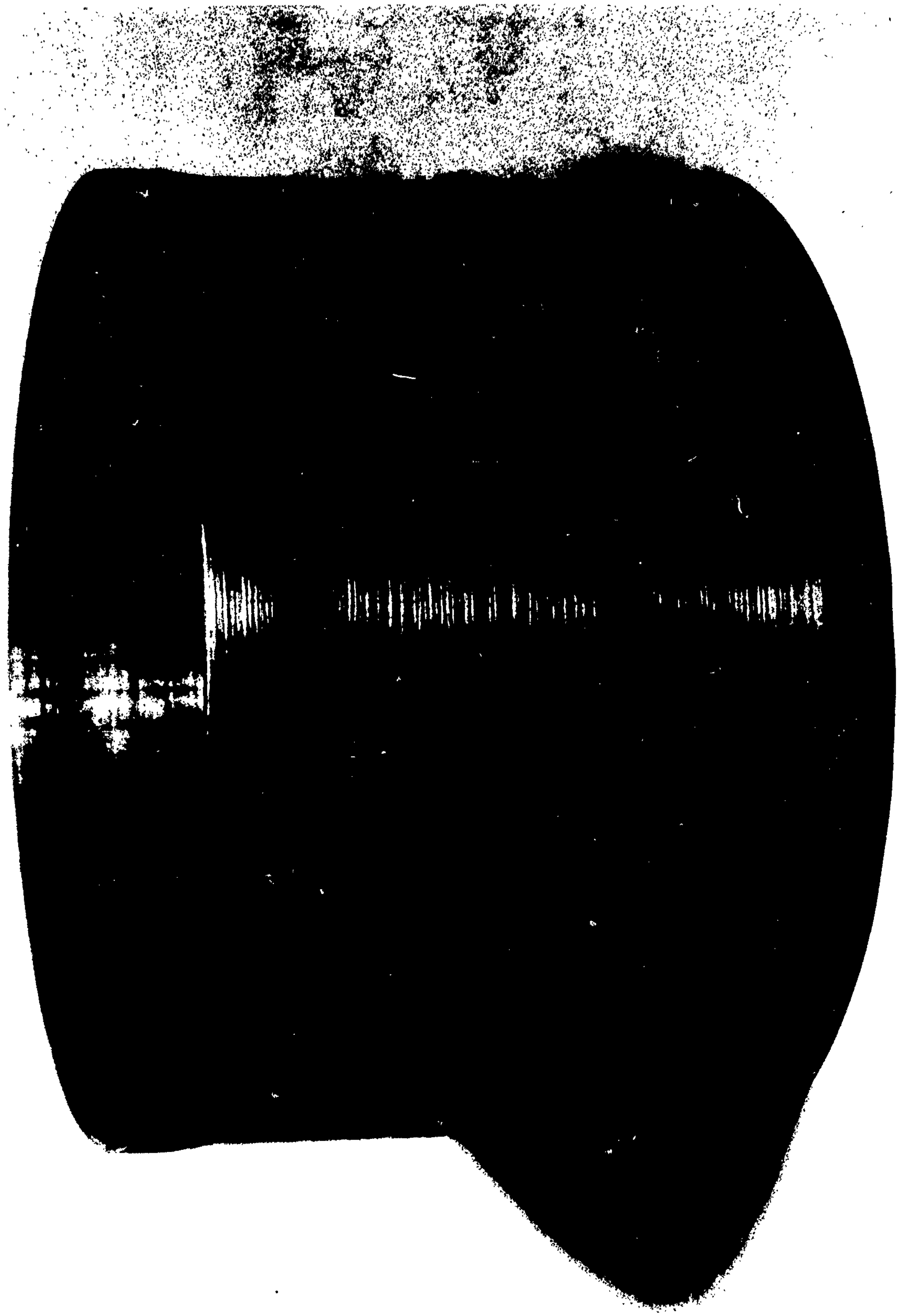


ALUMINUM MANDREL AND FIBERGLAS "LAY-UP" FOR 16-INCH DIAMETER COMPRESSION TEST CYLINDERS



TEST SET-UP FOR 16-INCH DIAMETER COMPRESSION TEST CYLINDERS

FIGURE 9



NUMBER 1, –1 16-INCH DIAMETER COMPRESSION TEST CYLINDER AFTER FAILURE BY CRUSHING

FIGURE 10

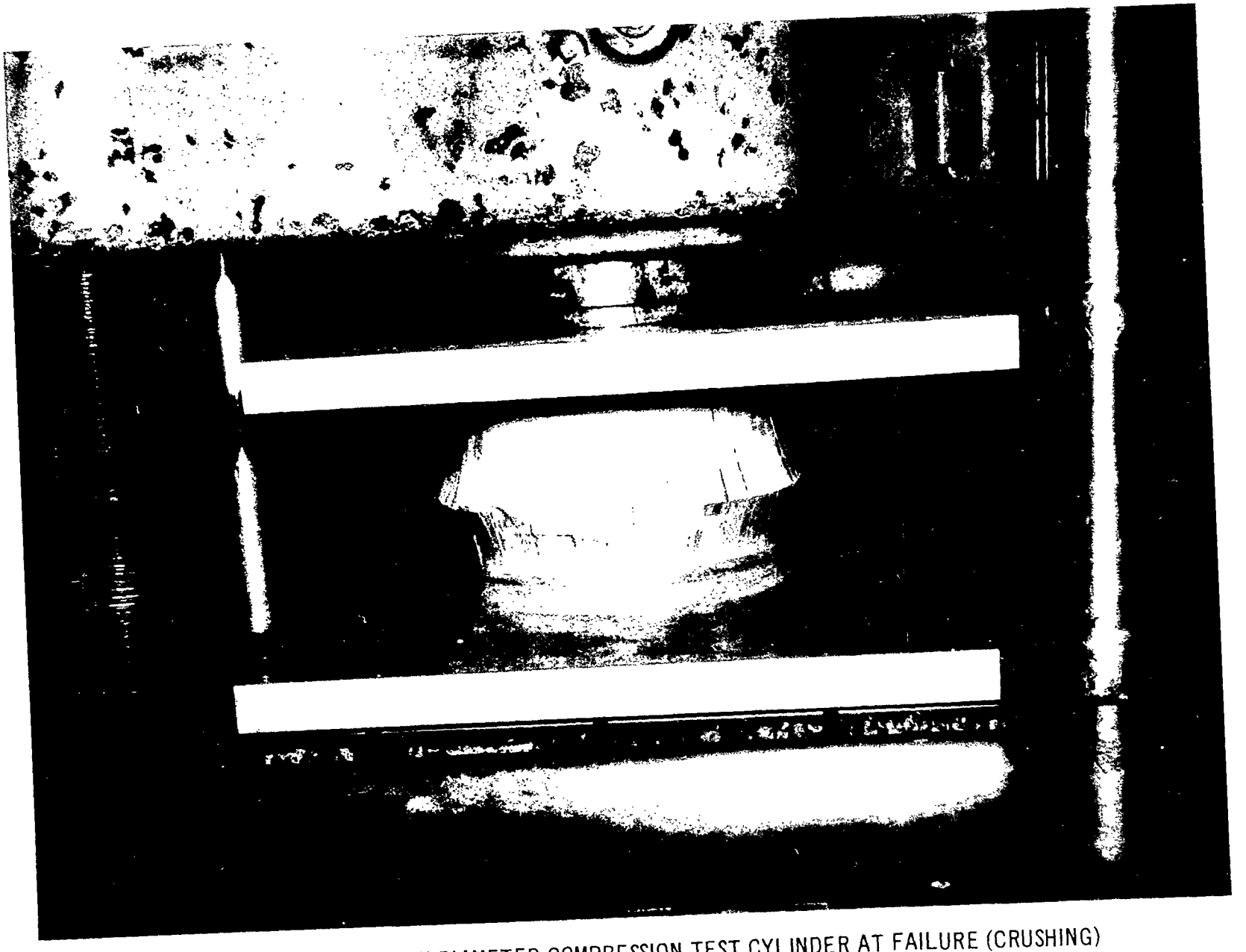


FIGURE 11

NUMBER 1, –505 16-INCH DIAMETER COMPRESSION TEST CYLINDER AT FAILURE (CRUSHING)

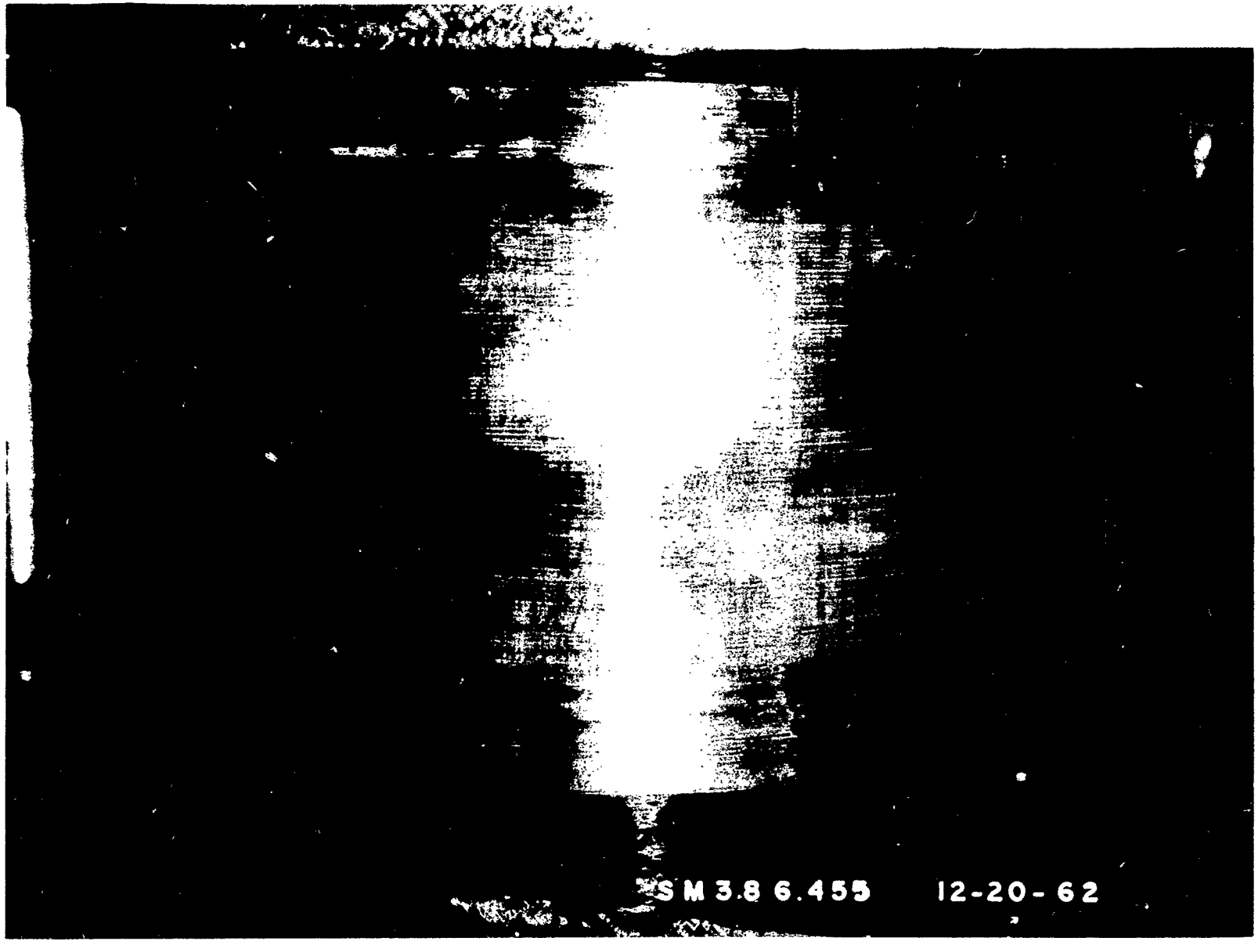


FIGURE 12

NUMBER 2, –503 16-INCH DIAMETER COMPRESSION TEST CYLINDER AT FAILURE (BUCKLING)

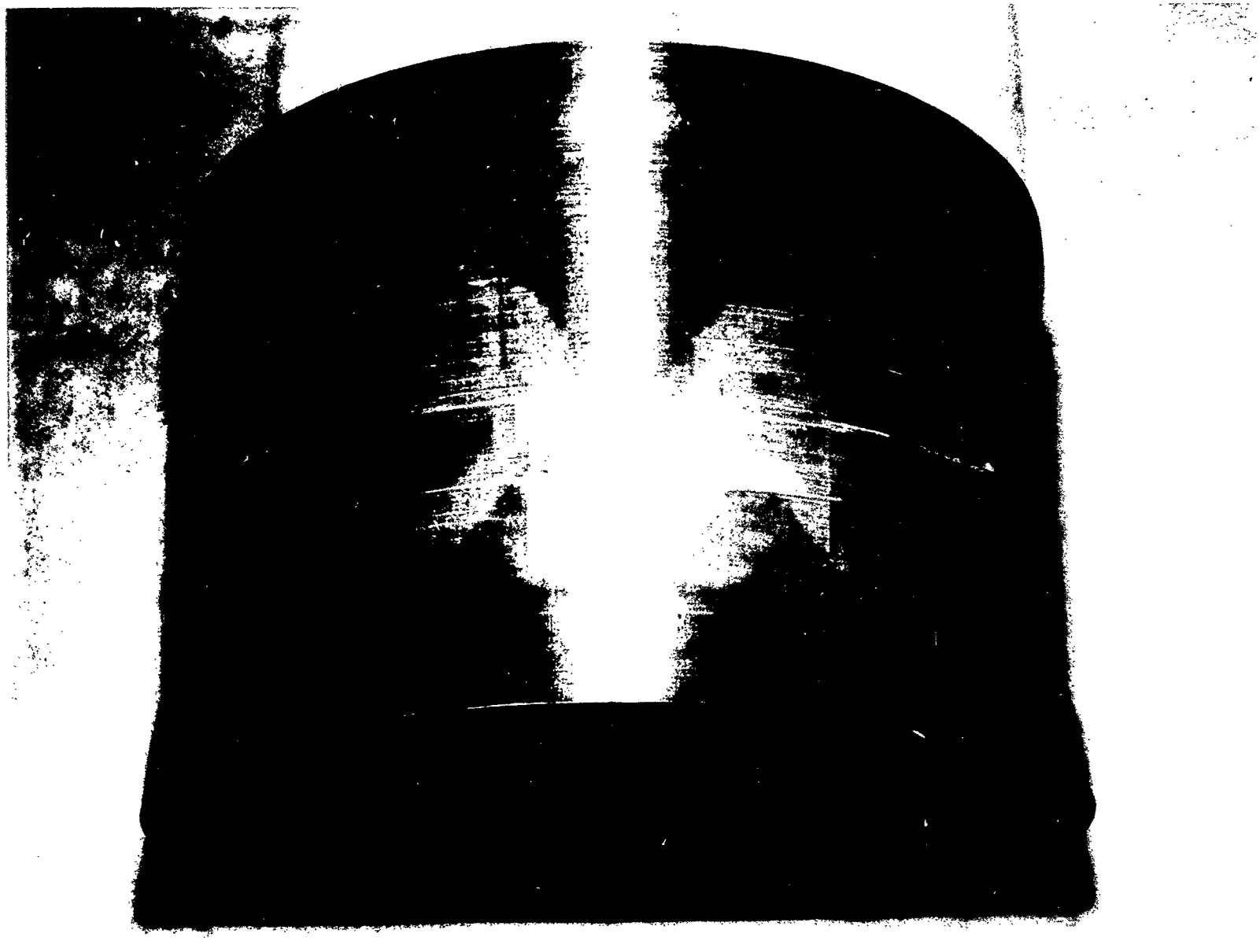


FIGURE 13

NUMBER 2, –501 16-INCH DIAMETER COMPRESSION TEST CYLINDER AFTER FAILURE BY BUCKLING

TABLE 6

16-In. Dia. by 12-In. Long Compression Test Cylinders

Code Drawing 1A35802		Material		Longitudinal Glass Thickness (In.)	Total Failure Load (lbs.)	Failure Mode
		Glass	Resin			
-1	No. 1	HTS	828-1031/ MNA/BDMA	.042	207,000	Crushing
-1	No. 2	HTS	828-1031/ MNA/BDMA	.042	205,000	Crushing
-501	No. 1	HTS	828-1031/ MNA/BDMA	.028	111,500	Buckling
-501	No. 2	HTS	828-1031/ MNA/BDMA	.028	107,000	Buckling
-503	No. 1	HTS	828-1031/ MNA/BDMA	.014	20,750	Buckling
-503	No. 2	HTS	828-1031/ MNA/BDMA	.014	18,700	Buckling
-505	No. 1	HTS	828-1031/ MNA/BDMA	.056	354,000	Crushing
-505	No. 2	HTS	828-1031/ MNA/BDMA	.056	366,000	Crushing

plastisols were selected on the basis of tests conducted by Elastomer Research. The tests consisted of casting various plastisols into fiberglas cylinders (see Figure 14) to investigate bonding, curing, cracking, etc. Bonding and curing procedures have been established for casting plastisols into fiberglas cylinders. These procedures will be discussed in detail in the Final Report.

2.1.8 Wedge Shear Test Specimens

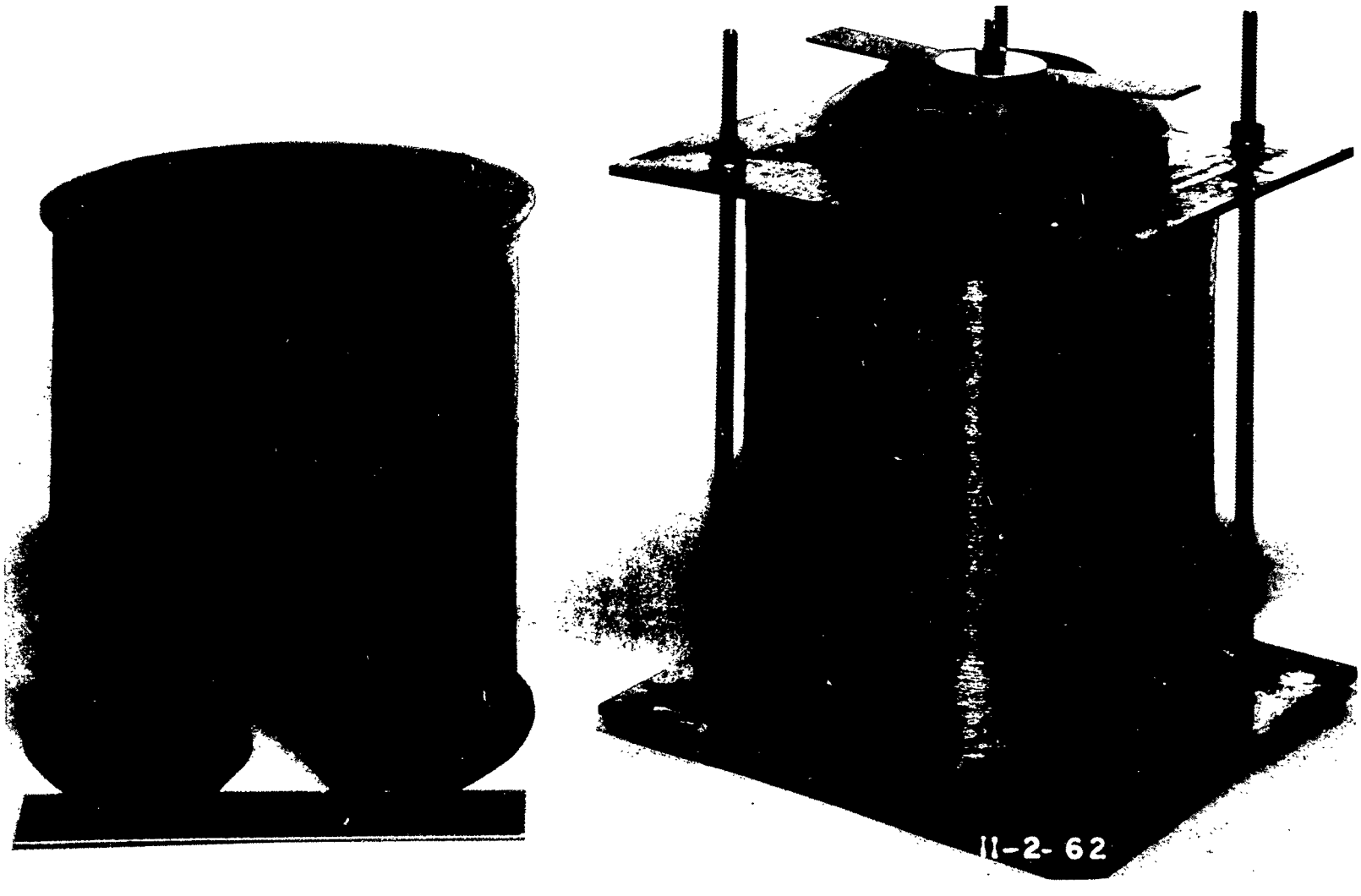
Four wedge shear test specimens (Dwg. No. 1A39826) have been tested The specimens were tested to evaluate a new stave anchoring concept. They were prepared by bonding steel end fittings to pre-molded staves. Before bonding, the staves were cleaned and sandblasted. The metal end fittings were vapor degreased, sandblasted, and treated with "Pre-Bond 700." The parts were then assembled with the appropriate adhesive (ER-89 or AF-300) and cured 2 hours at 200°F and 4 hours at 350°F.

Each of the specimens was mounted as shown in Figure 15. Then they were loaded in tension until failure. The bond in the "lap" area of each specimen failed at a low load (1,000 to 2,000 lb). Therefore, the joint strength at failure was almost entirely due to wedge action. The premature failure of the bond is believed to be due to eccentric loading during test. Combined bending and tension stresses caused the fiberglas laminate in each specimen to fail near the wedge (see Figure 16 for typical failures). Test results are shown in Table 7.

2.1.9 Wedge Anchorage Test Specimens

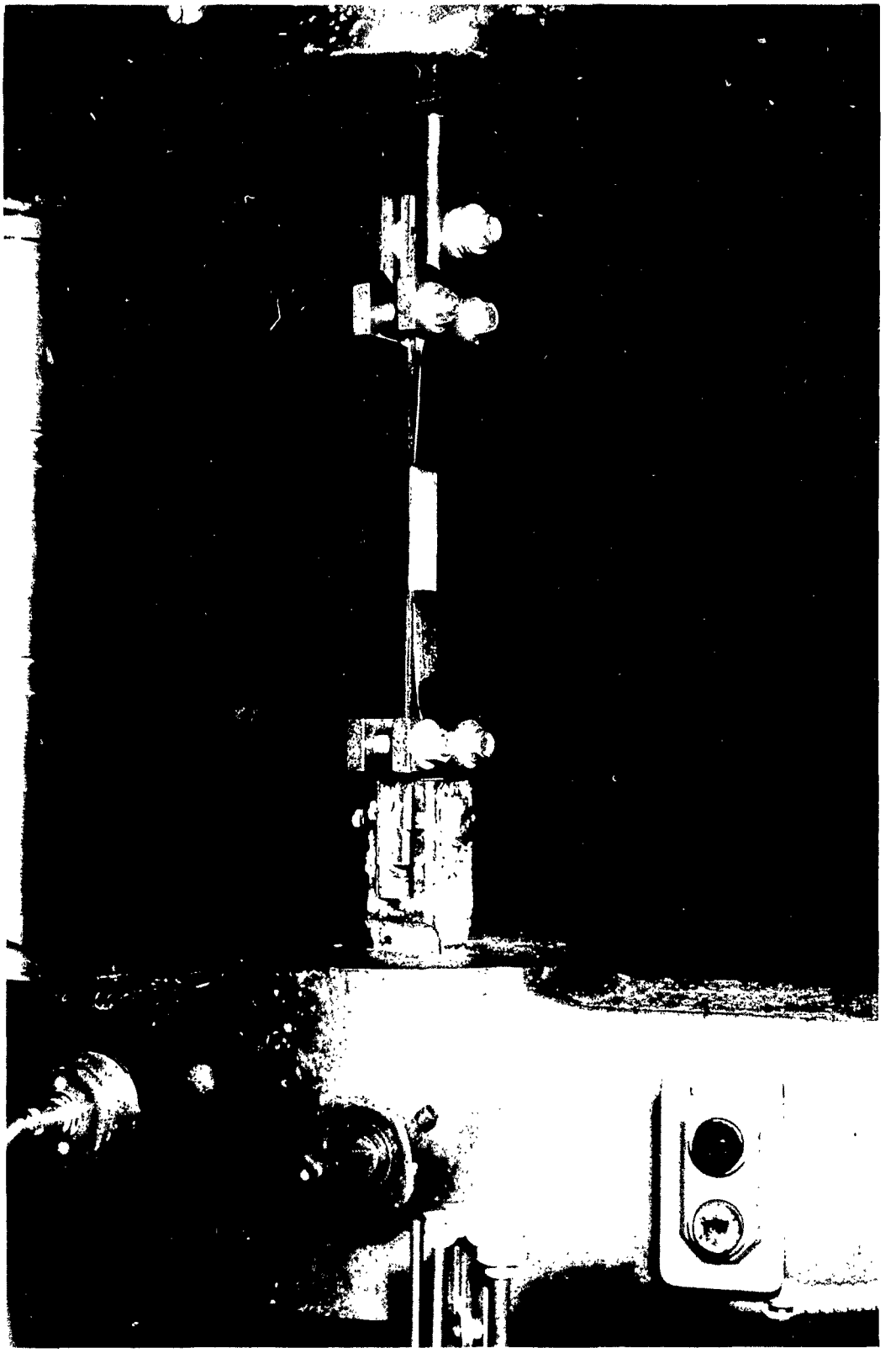
Four wedge anchorage test specimens (Dwg. No. 1A58249) have been tested. Fittings salvaged from the wedge shear test specimens were reworked

FIGURE 14



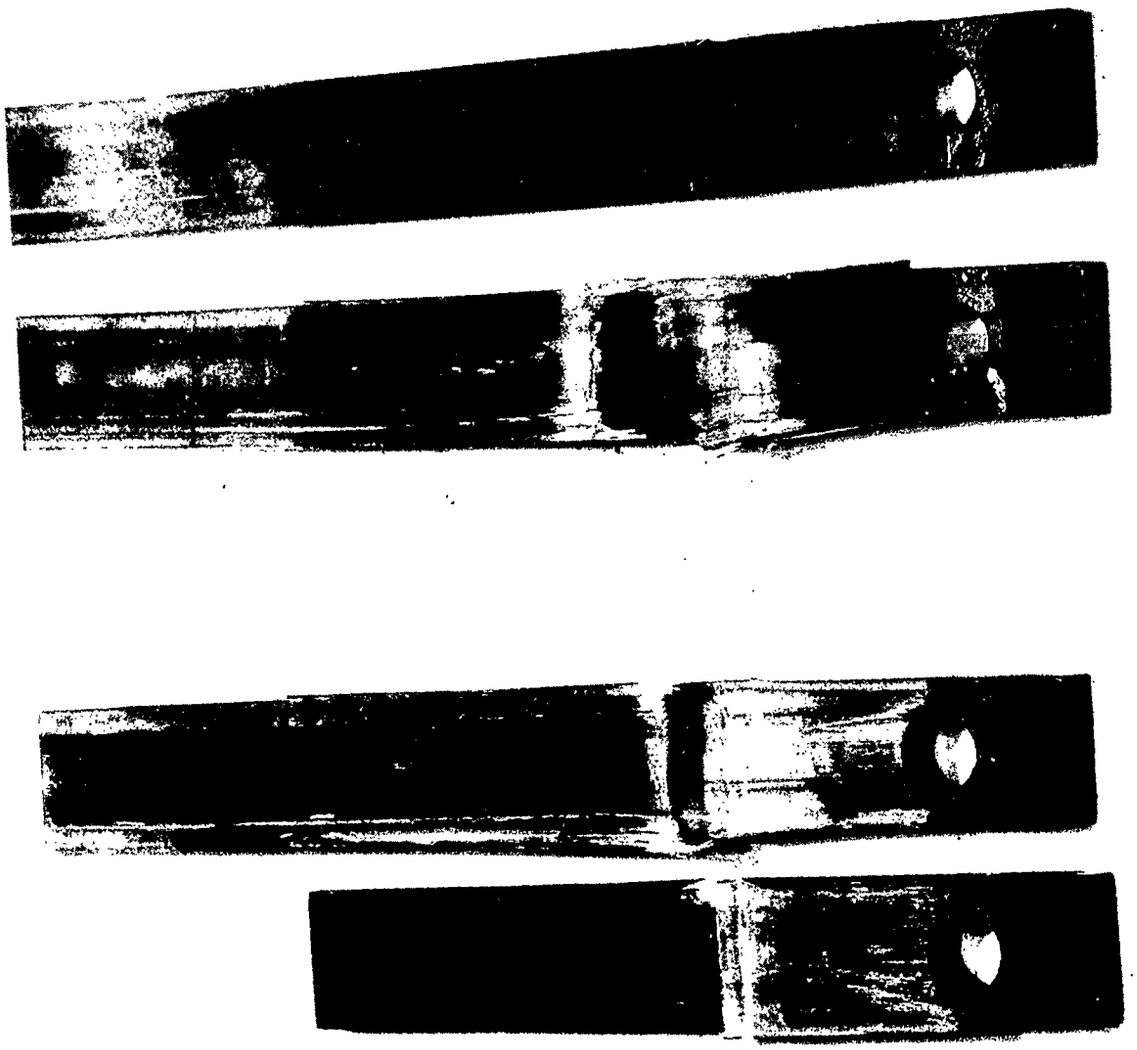
SAMPLE FIBREGLASS MOTOR CASE AFTER FUSION OF PLASTISOL

TYPICAL PLASTISOL (INERT PROPELLANT) AFTER CASTING INTO FIBERGLAS CYLINDER



WEDGE SHEAR SPECIMEN TEST SET-UP

FIGURE 15



TYPICAL FAILURE OF WEDGE SHEAR SPECIMENS

FIGURE 16

TABLE 7

Wedge Shear Test Specimens

Code Drawing 1A39826	Material				Total Load at Failure (lbs.)
	Glass	Resin	Metal	Adhesive	
-1 No. 1	HTS	X2638.6/ MNA/BDMA	4130 Steel	AF-300	14,050
-1 No. 2	HTS	X2638.6/ MNA/BDMA	4130 Steel	AF-300	10,600
-501 No. 1	HTS	X2638.6/ MNA/BDMA	4130 Steel	BR-89	7,500
-501 No. 2	HTS	X2638.6/ MNA/BDMA	4130 Steel	BR-89	12,225

for construction of the anchorage test specimens. The specimens were fabricated in the same way as were the wedge shear test specimens.

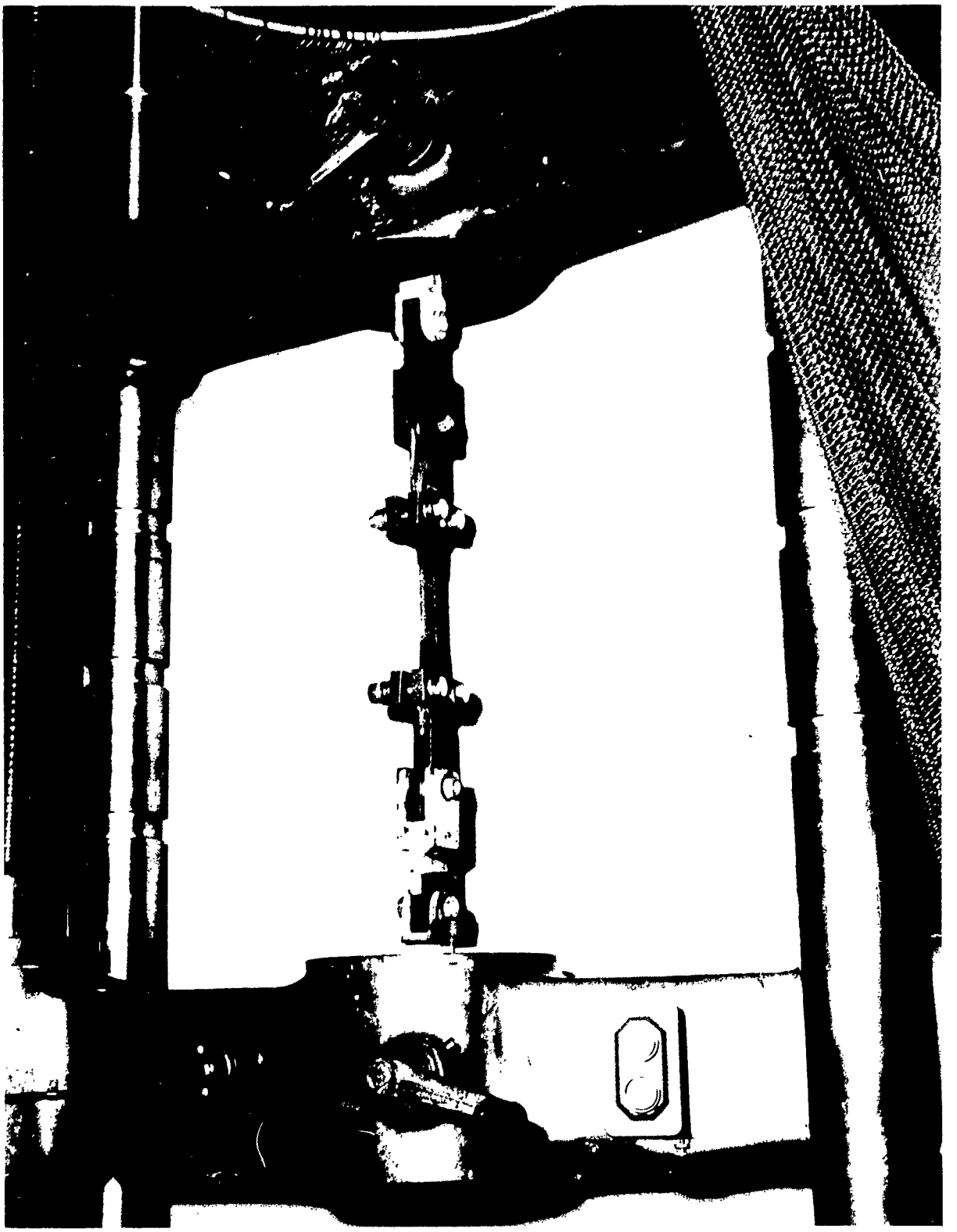
The specimens were mounted as shown in Figure 17. Then they were loaded in tension until failure. All the specimens failed due to the wedge pulling out of the joint (see Figure 18 for typical failure.) Test results are shown in Table 8.

2.2 43-In. Dia. Subscale Segments

Tooling for the 43-in. dia. segments is completed. Six staves for construction of the 43-in. dia. segments have been fabricated (see Figure 19 for picture of typical stave). The first two segments should be completed within four weeks.

Two of the 43-in. dia. test closures were assembled "back-to-back" and production clamps and bands were used to hold them together (see Figure 20). The closure assembly was pressurized, but several of the clamps "rotated" off at 250 psi, allowing the closures to separate and the "O" ring to extrude (see Figure 21). A dimensional inspection of the clamps showed that they had been machined out of engineering tolerance. The closures will be proof-tested again within two weeks. A stronger clamp retaining band has been completed for this second proof test. Also, the clamps have been re-machined within tolerance.

Redesigned clamps will be used for assembly of the 43-in. dia. fiberglas segments. The clamps were redesigned on the basis of results from the first proof test of the test closures. There will be three clamps for each joint instead of the 12 used on the original design. The end of each clamp



WEDGE ANCHORAGE SPECIMEN TEST SET-UP

FIGURE 17

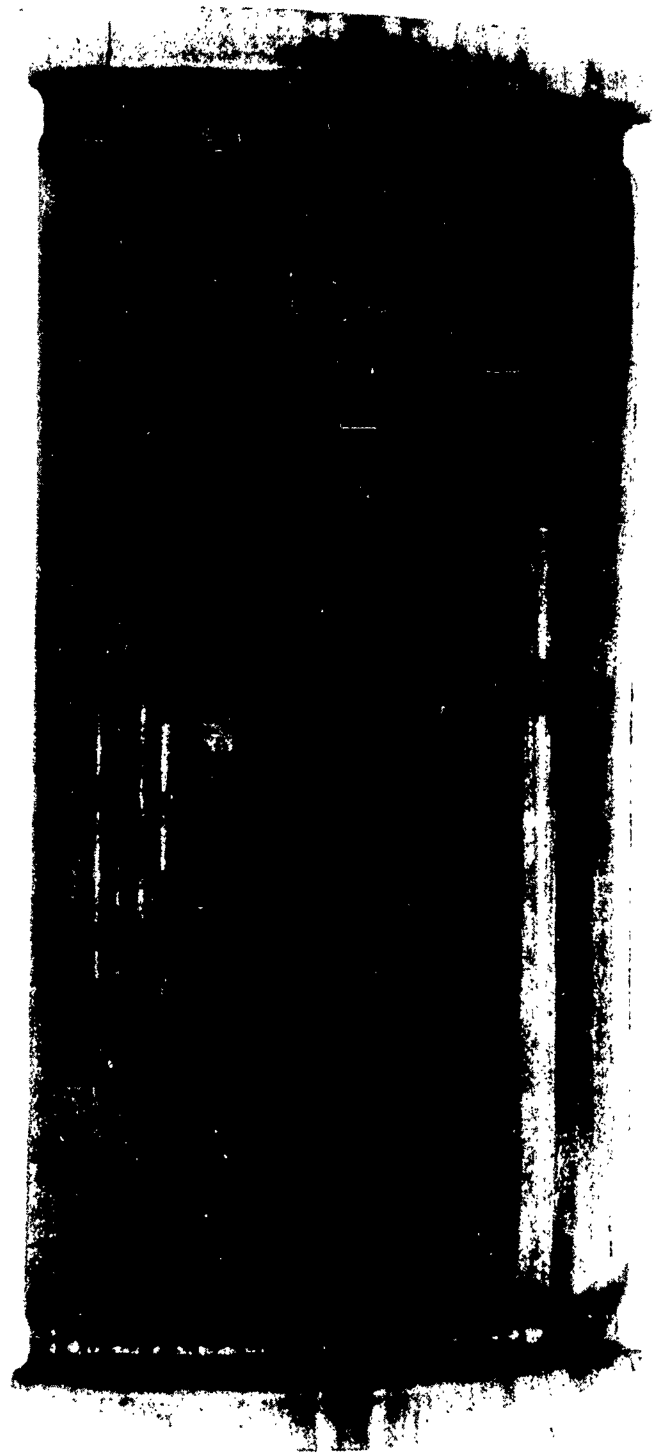
FIGURE 18

TYPICAL FAILURE OF WEDGE ANCHORAGE SPECIMENS

TABLE 8

Wedge Anchorage Test Specimens

Code Drawing 1A58249		Material				Total Load at Failure (lbs.)
		Glass	Resin	Metal	Adhesive	
-1	No. 1	HTS	828-1031/ MNA/BDMA	4130 Steel	AF-300	12,000
-1	No. 2	HTS	828-1031/ MNA/BDMA	4130 Steel	AF-300	14,900
-501	No. 1	HTS	828-1031/ MNA/BDMA	4130 Steel	BR-89	6,600
-501	No. 2	HTS	828-1031/ MNA/BDMA	4130 Steel	BR-89	8,000

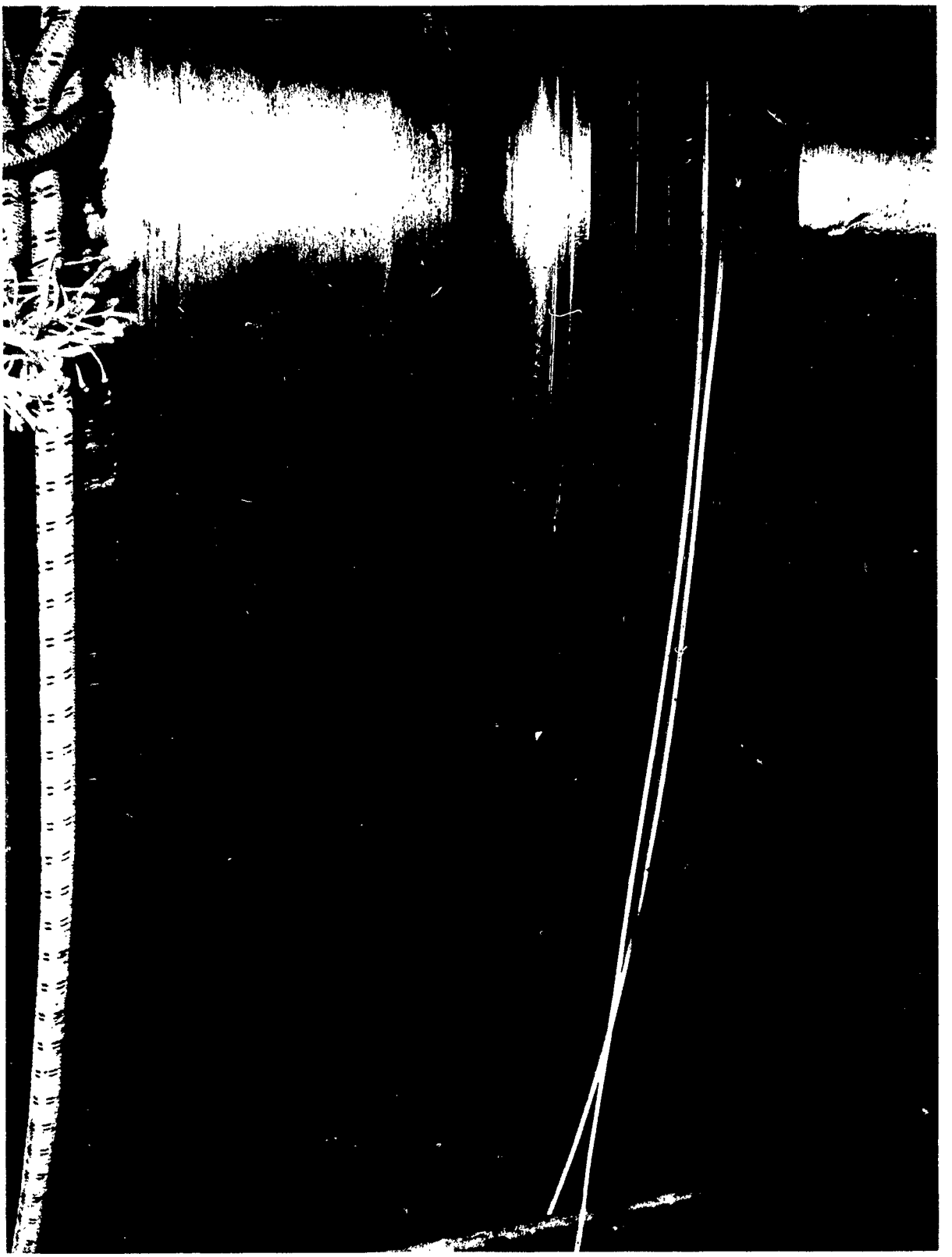


TYPICAL STAVE FOR 43-INCH DIAMETER SEGMENT ASSEMBLY

FIGURE 19

PROOF TEST SET-UP FOR 43-INCH DIAMETER TEST CLOSURES

FIGURE 20



"ROTATION" OF CLAMPS AFTER PROOF TEST OF 43-INCH DIAMETER TEST CLOSURES

FIGURE 21

will be bolted to the end of the adjacent clamp. This will eliminate the restraining band used on the original design. A drawing for these redesigned clamps has been completed (Dwg. No. 1A59706).

Fabrication and testing of the 43-in. dia. segments is considerably behind the originally established schedule. The following factors are primarily responsible for this lag.

a) Fabrication of tooling required for construction of the segments has been delayed by a temporary shortage of skilled personnel.

b) Results from tests of the 6-in. dia. by 18-in. long segmented joint test specimens indicated that the 43-in. dia. segment joint might fail at only 65% of design proof pressure. The joint design was modified to remedy this situation. This modification resulted in some delay in the completion of parts required for segment construction.

Douglas management has recently made several changes in an effort to bring fabrication and testing of the 43-in. dia. segments on schedule. These changes are:

a) The program has been given top priority so that construction will proceed as required without delay.

b) Engineering has been relocated from Douglas A-2 plant to A plant where the segments are being fabricated. This move will allow more efficient engineering supervision of segment fabrication.

c) Some of the man-hours originally allotted to engineering have been diverted to manufacturing since the engineering function has progressed ahead of schedule. These additional man-hours can be used effectively by manufacturing to get segment fabrication on schedule.

d) All key personnel associated with this project are concentrating on improved efficiency through close project coordination and regularly scheduled meetings.

It is expected that these changes will enable the final pair of segments to be completed and tested within the time originally allotted for the program.

2.3 Douglas-Funded Programs

Several Douglas-funded programs are being conducted to assist the segmented booster program. A brief description of work accomplished on these programs during the third quarter of segmented motor case development follows:

2.3.1 NOL Ring Test Program

Twenty-one NOL rings were tested in addition to the 50 rings reported in Quarterly Progress Report No. 2. All the rings were 2 5/8 inch I.D. (inside diameter) and were prepared per MRD-1P20019 (Materials Requirement Drawing) using 360 turns of single end HTS glass.

These rings were tested to evaluate five different resin systems. Test results are shown in Table 9.

2.3.2 Douglas Pre-Preg Tape Development and Production Program

Production of Douglas pre-impregnated fiberglas tape on the Douglas-funded tape-making machine has continued (see Figure 22). Quality control of the tape has been improved so that currently the resin content is varying from 20 to 24 percent (a 13 to 22 percent variation was reported in Quarterly Progress Report No.2). One-half inch wide by 6-mil thick tape is being

TABLE 9

NOL Ring Tests (For Resin System Evaluation)

Cure Cycle	Material		No. of Specimens	Average Ultimate Glass Stress (psi)
	Glass	Resin		
Gel at room temperature 3 hours at 250° F. 4 hours at 300° F.	HTS Single End	828/HHPA/ BDMA	4	291,000
1 hour at 185° F. 2 hours at 250° F. 4 hours at 350° F.	HTS Single End	826/MNA/ BDMA	5	263,000
Gel at room temperature 3 hours at 250° F. 4 hours at 300° F.	HTS Single End	332/HHPA/ BDMA	4	294,000
2 hours at 250° F. 4 hours at 350° F.	HTS Single End	828-1031/ MNA/BDMA	5	295,000
2 hours at 250° F. 4 hours at 350° F.	HTS Single End	E-714	3	252,000

DOUGLAS FIBERGLAS TAPE-MAKING MACHINE

FIGURE 22

produced at the rate of three pounds per hour (20 feet per minute). This production figure includes time required for machine cleanup, etc. The longitudinal hand lay-ups and staves for the bench test specimens and for the 43-in. dia. segments are being made from the tape.

2.3.3 Stave Anchoring Test Program

Various stave anchoring methods are being evaluated with an assembly as shown in Figure 23. This assembly consists of a test jig upon which pre-preg tape is "hand-laid" to form staves. These staves are then anchored by "overwrapping" with 20-end HTS rovings. Provision is made on each test jig for anchoring three staves (see Figure 24). In this way, three stave anchoring tests are obtained for each application of "overwrap."

Twelve staves have been tested so far. The highest ultimate load obtained during these tests was 42,000 lbs. per inch of stave width. It should be noted that this load is greater than the longitudinal load in a 160-inch diameter cylindrical motor case pressurized to 1,000 psi.

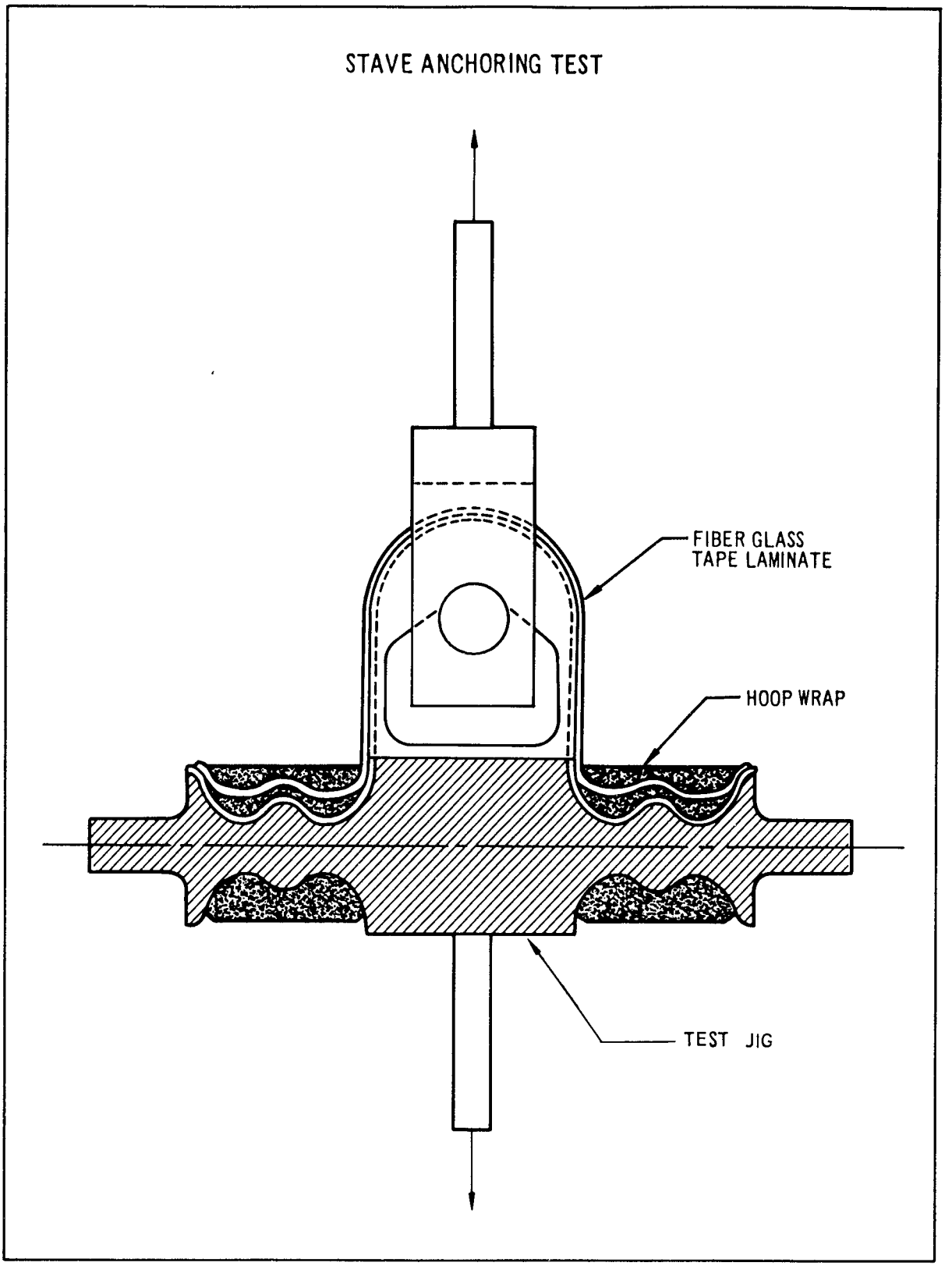
2.4 Outline of Work for Next Quarter

A brief description of work expected to be accomplished during the fourth quarter of segmented motor case development follows:

a) Bench Testing

The following work will be accomplished on the bench test program:

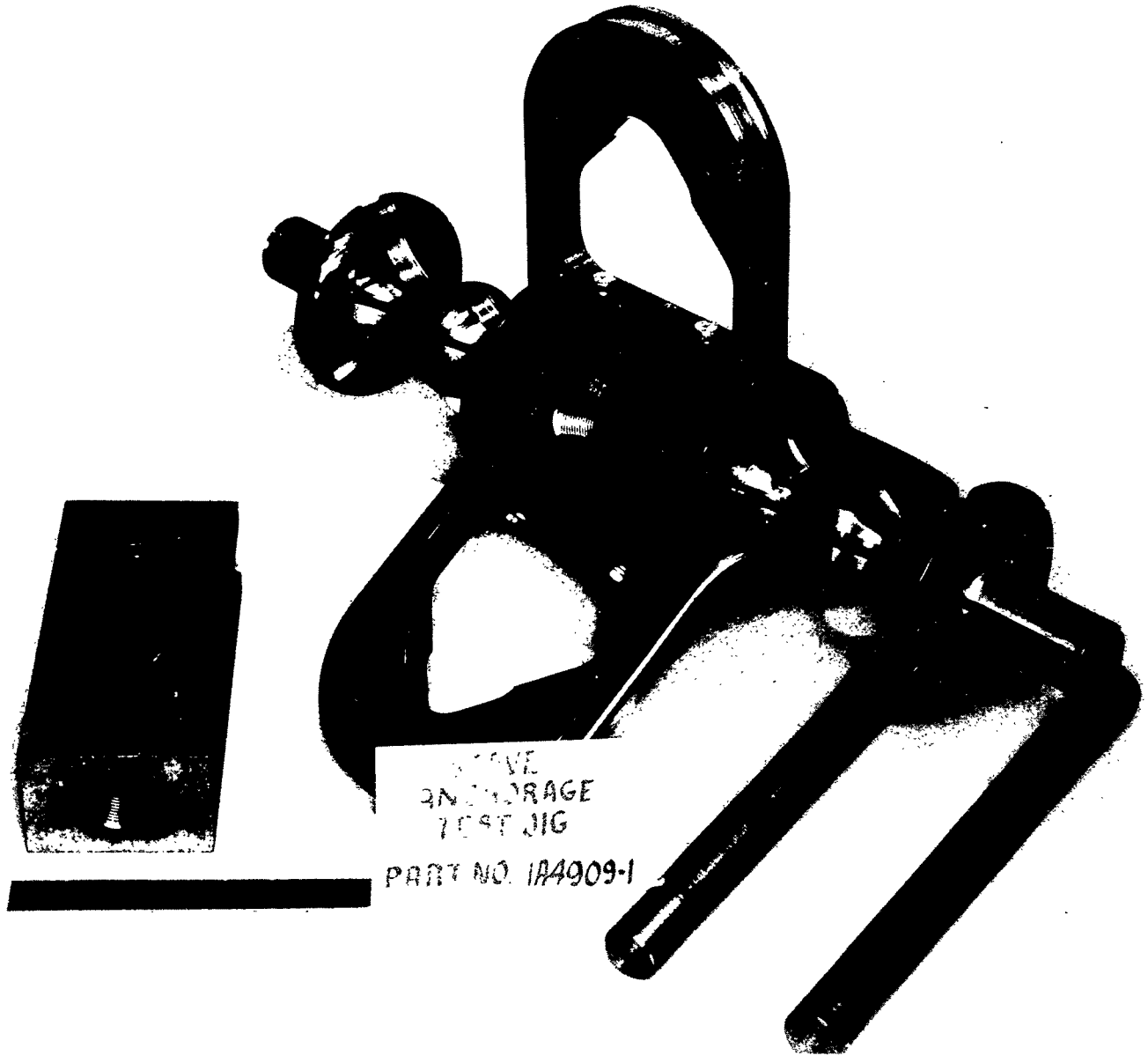
1. The sixth 6-in. dia. by 18-in. long segmented joint test specimen (Dwg. No. 1A35804) will be tested.
2. Twelve 25 1/2-in. dia. by 20-in. long compression test cylinders (Dwg. No. 1A35803) will be tested.



SKETCH OF STAVE ANCHORING TEST ASSEMBLY

FIGURE 23

FIGURE 24



STAVE TEST JIG FOR STAVE ANCHORING TESTS

b) 43-in. Dia. Segments

The 43-in. dia. test closures will be proof-tested again and three pairs of 43-in. dia. segments will be proof- and burst-tested.

c) Scale-Up Study

The feasibility study of scaling the 43-in. dia. subscale segments to full size (160 to 240-in. diameters) will be completed.

d) Final Report

The final report will be completed and will summarize results of the entire program. It will be "all-inclusive" and will not depend upon reference to preceding progress reports.

REFERENCES

1. Statement of Work, Contract No. AF 04(611)-8184.

2. Smith, R. V., "Subscale Bench Tests for Development of Segmented Motor Case, Model DA-95," Douglas Aircraft Company Memo STR-41181, dated August 29, 1962.

3. Smith, R. V., "Subscale Bench Tests for Development of Segmented Motor Case, Model DA-95," Douglas Aircraft Company Memo STR-41181-1, dated October 17, 1962.

4. Smith, R. V., "Subscale Bench Tests for Development of Segmented Motor Case, Model DA-95," Douglas Aircraft Company Memo STR-41181-2, dated November 28, 1962.

5. Carpenter, R. G. and Jeffus, T. R., "Quarterly Progress Report No. 1, Segmented Rocket Motor Case Program," Douglas Aircraft Company Report No. SM-42097, dated 17 August 1962.

6. Carpenter, R. G. and Jeffus, T. R., "Quarterly Progress Report No. 2, Segmented Rocket Motor Case Program," Douglas Aircraft Company Report No. SM-42516, dated 29 October 1962.

DISTRIBUTION LIST

AF-4	Rocket Research Laboratories, DGS
AF-11	Space Systems Div., Los Angeles
AF-12	ASTIA (10)
AF-14	Rocket Research Laboratories, DGPS
AF-15	Wright-Patterson AFB
A-3	Frankford Arsenal
A-10	Picatinny Arsenal
A-11	Redstone Arsenal (5)
A-22	Picatinny Arsenal
N-1	Bureau of Naval Weapons, RMMP-4
N-3	Bureau of Naval Weapons, RMMP-2
N-4	Bureau of Naval Weapons, RMMP-331
N-9	NOL/White Oak
N-14	ONR/Pasadena
N-18	Special Projects Office
N-23	Bureau of Naval Weapons, RRRE-6
D-7	Scientific and Tech. Info. Facility
D-8	NASA, Cleveland
D-9	NASA, Langley
D-10	NASA, Greenbelt
D-11	NASA, Huntsville
C-1	Aerojet/Azusa
C-5	Atlantic Research Corp. (2)
C-18	Hercules/Wilmington
C-24	Martin Company, Baltimore
C-32	Forrestal Research Center
C-37	Solid Propellant Information Agency (3)
C-39	Thiokol/Huntsville
C-41	Thiokol/Elkton
C-51	Goodrich/Rialto
C-61	Rocketdyne, Canoga Park (3)
C-65	Lockheed/Redlands (3)
C-72	Aerojet/Sacramento (3)
C-73	Thiokol/Wasatch (2)
C-75	Martin Company/Orlando
C-78	Wright Aeronautical Div.
C-88	Hercules/Rocky Hill
C-94	Minn. Mining and Mfg. Co. (2)
C-97	Ford Motor, Aeromutronic Div.
C-107	General Electric Co., Cincinnati
C-116	Space Technology Laboratory
C-124	United Technology Corp.
C-125	Aerojet/Downey
C-129	Aerospace Corporation (2)
C-133	Thiokol/Ogden

Douglas Aircraft Company, Inc. Missiles & Space Systems Division Santa Monica, California QUARTERLY PROGRESS REPORT NO. 3 SEGMENTED ROCKET MOTOR CASE PROGRAM by R. G. Carpenter, T.R. Jeffus, Jan. 1963, 54 P. incl. illus. tables. (Proj. No. 3059; Contract AF04(611)-8184) Unclassified Report Quarterly report No. 3 on R & D directed toward development of lightweight motor case segments, culminating in a design applicable to large (160 to 240 in. diameter) segmented solid propellant rockets.	UNCLASSIFIED	Douglas Aircraft Company, Inc. Missiles & Space Systems Division Santa Monica, California QUARTERLY PROGRESS REPORT NO. 3 SEGMENTED ROCKET MOTOR CASE PROGRAM by R. G. Carpenter, T. R. Jeffus, Jan. 1963, 54 P. incl. illus. tables. (Proj. No. 3059; Contract AF04(611)-8184) Unclassified Report Quarterly Report No. 3 on R & D directed toward development of lightweight motor case segments, culminating in a design applicable to large (160 to 240 in. diameter) segmented solid propellant rockets.	UNCLASSIFIED

Douglas Aircraft Company, Inc. Missiles & Space Systems Division Santa Monica, California QUARTERLY PROGRESS REPORT NO. 3 SEGMENTED ROCKET MOTOR CASE PROGRAM by R. G. Carpenter, T. R. Jeffus, Jan. 1963, 54 P. incl. illus. tables. (Proj. No. 3059; Contract AF04(611)-8184) Unclassified Report Quarterly Report No. 3 on R & D directed toward development of lightweight motor case segments, culminating in a design applicable to large (160 to 240 in. diameter) segmented solid propellant rockets.	UNCLASSIFIED	Douglas Aircraft Company, Inc. Missiles & Space Systems Division Santa Monica, California QUARTERLY PROGRESS REPORT NO. 3 SEGMENTED ROCKET MOTOR CASE PROGRAM by R. G. Carpenter, T. R. Jeffus Jan. 1963, 54 P. incl. illus. tables. (Proj. No. 3059; Contract AF04(611)-8184) Unclassified Report Quarterly Report No. 3 on R & D directed toward development of lightweight motor case segments, culminating in a design applicable to large (160 to 240 in. diameter) segmented solid propellant rockets.	UNCLASSIFIED

MISSILE & SPACE SYSTEMS DIVISION
DOUGLAS AIRCRAFT COMPANY, INC
SANTA MONICA, CALIFORNIA